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ABSTRACT

In 2 years, RMIT University (Melbourne, Australia) set up an online learning system for 50,000 students. The development of the RMIT Distributed Learning System has taken the University from a cottage industry model to a fully fledged enterprise system for flexible online learning, integrated with the University's student administration system and capable of integration with the PeopleSoft student system when it goes live. This paper reviews the infrastructure and basic services required for this level of growth. First, a background is briefly sketched, followed by a list of initial design objectives for the distributed learning system (DLS). The DLS was built and deployed in four phases. Each of these phases is described. RMIT is simultaneously implementing four enterprise systems in parallel, with intention to integrate them during 2001. These four systems are described. The rollout of the DLS brought into sharp focus the problems of deploying an enterprise system across a large intranet in which could be found non-standard servers, different versions of network software, and variations in configuration of the network software. The parallel information technology (IT) infrastructure refurbishment is outlined, and outcomes including the success of the program are discussed. (Contains 11 references.) (AEF)

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From Genesis to Infinity
or
from 0 to 50,000 Online Students in 2 Years

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Abstract

In two years RMIT University, Melbourne, Australia set up an online learning system for 50,000 students. This presentation reviews the infrastructure and basic services required for this level of growth.

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Background

RMIT University is a large and diverse institution that provides programs to 52,000 students, from Certificate and Diploma (Community College) through 3-, 4- and 5-year bachelor (graduate) programs, to Masters and PhD. More than 20% of enrolments are direct fee-paying students from Asia and Oceania, with the balance funded by a direct government grant to the University.

During 1995 the Deputy Vice-Chancellor (Provost) initiated the development of a comprehensive Teaching and Learning Strategy. The strategy would provide the blueprint for radical and systematic change to the University's operations and set the student at the centre of a customer-focussed system that would compete effectively in a globalised education market. The strategy was driven partly by the decline in government funding, but primarily by a realisation that there would be a massive growth in demand for education, particularly in Asia, as the old-world economy was giving way to a global knowledge-based economy fuelled by the Internet.

During the 1990's RMIT, like many other educational institutions, experimented with IT-based flexible learning systems via a combination of mechanisms, including encouraging enthusiastic early adopters of technology and using a range of corporate sponsored projects. These learning systems were typically content oriented with an emphasis on the use of multi-media authoring tools and the maximum use of high-bandwidth content.

The University established a major project in 1998, designated the IT Alignment Project (ITAP), under the direct management of the Deputy Vice-Chancellor. The brief was to provide a strategic plan for the use of IT in teaching and learning by reconsidering all relative elements from student administration, through IT infrastructure to flexible learning technology.

The specific outcomes of ITAP were that the University Council (Senate) adopt the following objectives:

- Completely redevelop the student administration processes and adopt consistent corporate student-centred processes based on the 'customer is king' approach to customer relationship management.
- Acquire a student administration IT system that is web-enabled and capable of providing maximum student accessibility, automation and self service.
- Develop a single flexible learning platform called the Distributed Learning System (DLS) based on structured content delivery using an eclectic mix of media but with an emphasis on pedagogical design for flexible learning and binding the learners into a virtual learning community.
- Radically realign the corporate and departmental IT infrastructure to suit the needs of teaching and learning.
- Retrain academic, administrative and IT staff to effectively exploit the investment in IT.
- Complete refurbishment of the University web presence by using dynamic delivery of web pages sourced from an XML database of authorised meta-data catalogued content.

The University committed A $50 million over four years for strategic investment to achieve these objectives, starting in 1999. The development of the Distributed Learning System is the subject of this paper.

Distributed Learning System (DLS)

The initial design objectives for the DLS were as follows:

1. Create a single system to use across the whole University flexible enough to satisfy the full range of academic requirements and sufficiently adaptable to enable the integration of new tools as they become available.
2. Use software from vendors committed to the IMS standards, with an emphasis on buying commercial software rather than building from scratch.
3. Integrate software into a Learning Hub (portal) in order to provide straight-forward access by students into a variety of integrated learning system tools.
4. Integrate with the legacy student administration system to enable automatic control of access by students to only the courses in which they are enrolled.
5. Integrate with the Novell Network Directory Services (NDS) so that students require only one usercode/password combination to access IT resources within the University.
6. Create a scaleable three tier architecture with an Oracle database backend and platform independent (i.e. Macs and PCs) thin client.
7. Make the DLS disaster proof—use backup and business continuity specifications equivalent to major ERP systems (student administration, finance etc).
8. Use rapid prototyping to achieve a useable benchmark system quickly in order to provide academic staff with a production system on which to refine their understanding of the pedagogy of flexible learning.

Because of deficiencies in the commercial software and delays in standardising the University IT infrastructure, some short-term compromises had to be made to these objectives in order to produce a production system quickly. These were mainly workarounds that will be replaced as soon as the circumstances extraneous to the DLS permit.

Development Approach

The DLS was built and deployed in four phases. Phase one started in October 1998 with the establishment of the production team and a timeframe of five months to deliver the first working prototype in readiness for the (southern) fall semester of March 1999.

A systematic evaluation of commercially available learning management system (LMS) software was conducted (Lord, 1999,b) and a number of IMS participant vendors were identified.

A suite of tools was selected, so academics would be able to choose a tool that most closely matched the requirements of the learning activity they would be implementing online. Maximum involvement by academic staff as early as possible in the first phase was seen as critical to successful deployment.

Phase 1

For the first phase, it was decided to offer a prototype with a common login and front-end from which academics and students could choose to:

- access a learning management software,
- access an online content generator,
- have direct access to Internet sites.

Macromedia Pathware was chosen for the front-end and the content generator as several departments already used it for the latter purpose.

BlackBoard CourseInfo was selected for the primary learning management system (LMS). This product allowed easy Internet publishing by staff members plus offered a broad cross-section of features, including online assessment, discussion, file submission, and self-administration by staff members.

Question Mark Perception, for improved online assessments and surveys, and O'Reilly WebBoard, for online discussion and chat were included in phase 1.

A simple web registration tool for students was developed because of insufficient time to integrate the DLS with the University student records system. Academics had a choice of requesting students to self-register, or they could provide student lists to the DLS team administrators for input.

The DLS was developed using MS-SQL as the back-end because Blackboard CourseInfo did not support Oracle at this time. The hardware platform was a single Compaq Proliant server with 45 Gb of disc running NT, the University standard operating system.

The system ran for 24 hours a day 7 days a week, but officially only supported standard office hours. (Developers did, however, monitor the system during the night and on weekends.) The prototype was successful and was significantly over subscribed, as the original plan was to run a maximum of 20 courses.

A support desk was established to provide telephone assistance to students and academic staff in the use of the DLS.

For a summary of the relevant statistics for each of the phases, see Table 1: Phase Overview, in the Appendix.

Phase 2

Phase 2 development commenced in May 1999 for release in July 1999. The purpose of this phase was to provide additional functionality and to enhance the overall system performance.

The performance of Macromedia Pathware as the front-end and the mechanism for integration of the toolset was unsatisfactory particularly over slow connections. This was because of its dependence on Java and the need to download the driving software at each initial login to the system. To obviate this problem a new faster GUI interface denoted the 'Learning Hub' was written in ASP. For an example of a screen capture of the Learning Hub see the Appendix, Example 1: The DLS Learning Hub Interface.

The first level of Novell Network Directory Services (NDS) integration with the DLS was a major part of this phase. It was built using an LDAP query to the NDS passing the user ID and password and returning confirmation of a match. This proved to be a very slow process partly because of the replicated nature of the NDS database and the federated structure of the RMIT IT infrastructure. Also, because each department with a server on the Intranet had the ability to act autonomously in respect to the registration of users, the NDS tree was overly complex, logically fractured, and had a large numbers of duplicated entries. Consequently 'walking' the NDS tree was slow. A workaround was devised as an interim measure while separate action to standardise and rationalise the IT infrastructure was undertaken.

The workaround simulated the Novell catalogue service by walking the NDS tree once and building a database of user IDs and context that located the part of the tree where the user was registered. The authentication process used the user ID as an index into the database and returned the context that, along with the ID, was passed to the NDS. The database was rebuilt nightly to remain current. This approach significantly improved login times, but required nursing through

the spring semester of 2000 due to intermittent faults that caused the failure of the overnight rebuild of the database, to go to completion.

With the use of NDS for user authentication, lost passwords, caused by the fractured nature of the NDS tree, constituted a major element of the help sought by students and these had to be passed to departments for solution. This problem was alleviated by giving the help desk access to change passwords.

Student registration was enhanced by adding a Registration Wizard that stepped students through the registration process. This module permitted students to self-register which was useful when their details were slow to enter the DLS via official university systems.

Also automated 'database connectors' were introduced, which enabled each of the application back-end databases to be automatically updated with student-course registration data, in batch mode overnight. Such a system design enabled a wide range of tools to be incorporated into the DLS in a cost effective manner.

While these processes worked satisfactorily from a technical point of view there was an issue in that academic staff could not understand why there was not an instantaneous registration of their students immediately after the start of semester. This was caused by the processing required by the student administration legacy system which is currently being replaced with PeopleSoft Student. Other problems related to inappropriate business processes, which had not previously shown up prior to real-time access controls being implemented.

Some additional services were added, including access to an online information database, by providing direct links to the bookstore and the Library. An additional server with a second copy of the prime LMS application (Blackboard CourseInfo) was added to enable academic staff to develop and test online subject content away from the production environment.

Phase 3

Phase 3 commenced November 1999 and was completed mid-February for the start of Semester 1, 2000. This stage required redevelopment of the system in terms of functionality, security and scalability in preparation for initial expansion to 25,000 students, 600 courses and 1500 staff members, then ultimate expansion to 52,000 students.

This phase involved a total code review, as some code had been created using code generators and there was concern that it was not efficient enough to support ultimate access by the total student population of 52,000 students. Where required the code was revised to ensure scalability.

It was at this time that the security was improved via the addition of SSL authentication for user IDs and passwords, plus extension of authentication checking was added so that each web page checks to ensure that the user was in fact currently logged in.

The student interface required additional functionality to improve the information provided to both students and staff about their schedules and the system. The interface was modified to include a calendar for students and a direct link for staff to the email tool Novell GroupWise, including display of their diary and number of unread messages. Also added were 16 online reports with Chrystal reports, as well as an improved Administration Tool. The Approval process was decentralised so the staff members teaching the courses could use the DLS to approve the students who were registering to learn online, rather than having the DLS team approve them.

As part of the ongoing integration with University data, a connector to University staff data was added to automatically import full-time staff records.

This phase also included integration with an RMIT developed online quiz package, WebLearn. This product was already in use by 3000 students. An ODBC connection was installed for communication between WebLearn which operated on Unix and the DLS which operated on SQL server in an NT environment. The only non-NT system was purchased for WebLearn and to also run timetabling software.

It was estimated that during 2000, the system would experience between 200,000 and 300,000 hits per day.

In order to handle anticipated increased number of students, plus provide some level of hardware redundancy, the hardware was increased from two to six servers, including one cluster with two web farm servers and two SQL servers. The web farm servers provided redundancy for each other. One SQL server was configured to run the non-distributed version of CourseInfo; it also provided redundancy for the second server which ran WebBoard and Question Mark Perception. The SQL databases were actually located on a RAID 5 array, which itself provided in-built redundancy if one hard disk should fail. For more information, see the Appendix, Diagram 1: DLS Hardware diagram.

Phase 4

Phase 4 development commenced May 2000 and was completed mid-July for the start of Semester 2, 2000. The object of this stage was to improve the robustness of the DLS, provide the infrastructure for 52,000 students, and to add functionality.

The highest priority for this phase was to improve the stability of the DLS. Primary focus of development was on the NDS Catalog Simulator module. A memory leak was resolved and design was improved, and the module was moved to a dedicated server. This decreased login time and improved reliability.

The hardware was reorganised for improved stability. A second server was installed to provide scalability to 52,000 students via program level access to WebBoard, whereby discussion areas could be set up for all University programs. CourseInfo was moved to a dedicated server for increased stability, scalability and performance.

During this phase, the cluster was deconstructured to reduce the complexity of the hardware configuration and resulting problems. Load balancing was switched off and will be replaced with hardware load balancing some time in late 2000.

Software improvements and further integration included:

- the option to remove all browser buttons so staff could select whether or not students could see the buttons;
- usability improvements to the login page and improved help;
- the addition of some end-of-semester functionality to assist with administration of courses, including courses and student archive functionality within the DLS;
- the addition of more statistical reports and some label generating reports;
- direct access to the student email system, NIMS (Novell Internet Messaging System). Unfortunately transparent login was not possible with NIMS, so students still have to re-enter their user ID and password.

With phase 4, the cluster has been disassembled and hardware redundancy which is easier to maintain in the University environment, is being implemented.

By the 4th quarter 2000 the full disaster recovery plan will be implemented, the system will be supported 24 x 7, and it will have redundancy for all servers. Business continuity plans include locating the redundant servers in a second building, ghosting all servers for quick disaster recovery, and performing hot backup to hard disk on the redundant server for quick restore.

All servers will have two hard disk drives and two power supplies, and use RAID 5 disk arrays that can experience one hard disk failure without disturbing normal server operations. Monitoring is currently provided by in-built 'Compaq Remote Inside Boards' plus 'What is Up Gold'. A software package with more elaborate call escalation definition is currently being investigated.

Proposed Future Development

RMIT is simultaneously implementing four enterprise systems in parallel and intends to integrate them all during 2001. The four systems are the:

- SAP HR and Finance system—this system went live in May 1999 and is about to undergo a major upgrade,
- Academic Management System (AMS) using PeopleSoft Student 7.6—due to go live in April 2001,
- Distributed Learning System,
- rationalisation of all the websites in the University into a single meta-data catalogued XML database using SIM technology—see http://www.simdb.com.

The DLS-AMS, AMS-SIM and DLS-SIM integration provide some significant technical and policy issues but also major opportunities to enhance the performance and customer perceptions for the DLS. Each of the AMS, SIM and DLS will provide portal functionality and there is a major challenge in seamlessly connecting these together.

SAP HR and Finance system

The DLS will be insulated from the SAP HR/Finance system by the AMS – all data required from SAP will be extracted from the AMS.

DLS-AMS Integration

Staff and students will be able to access HTML Access (previously Campus Connection) inside the RMIT virtual private network (VPN). The NDS-Single Sign-on system will control student entry into the VPN. Once authenticated into the VPN, students will be able to access all systems (SIM, DLS and AMS) without having to re-authenticate. HTML Access will check the student's identity on entry to the portal via an LDAP query to the NDS. Once in HTML Access, the student will only be able to transition to the DLS from an enrolled course and this information will be passed to the Learning Hub, which will use the same LDAP process to check the user identity and then pass through to the specific course area.

The AMS will populate the NDS and hence all enrolled students will be automatically registered to use IT resources within the VPN. With PeopleSoft 7.6 this will be done by file download/upload but it is anticipated that with version 8 the NDS will be updated on a unit record basis at the time a student enrols. This will significantly reduce the latency so that students who enrol offshore via the web will be able to access online learning resources immediately after their fees clear.

DLS-SIM Integration

Rationalisation of the web using meta-data catalogued XML front-ended by a very fast search engine will allow RMIT to create and manage web content efficiently. The primary authoring tool, Microsoft Word and standard templates permit users to create combined image and text documents which are automatically converted to XML, catalogued and stored in the database. Any other resource can also be catalogued and stored in an XML 'wrapper'. This technology also provides opportunities to enhance the DLS by enabling the construction of courses using meta-content. Content will be stored as meta-data catalogued objects in the XML database and served dynamically to students. This will facilitate the reuse of learning objects, provide the capacity to build special purpose courses quickly and enhance the flexibility of course design by adding another level of content connectivity beyond that offered by the LMS tools.

Parallel IT Infrastructure Refurbishment

The DLS is the first University-wide system to be deployed for general student use at RMIT. Until now student IT services have been provided on a departmental or faculty basis. The rollout of the DLS brought into sharp focus the problems of deploying an enterprise system across a large intranet in which could be found non-standard servers, different versions of network software and variations in configuration of the network software.

University Network

The RMIT (intra) network is a loose federation with a central core switching ATM mesh maintained by the Information Technology Services (ITS) department, and local switching and servers owned and maintained by academic departments. A degree of uniformity was achieved by site-licensing Novell Netware and NT and requesting consistent version releases across the platform.

Under the ITAP brief for '*Radical realignment of the corporate and departmental IT infrastructure to suit the needs of teaching and learning*' (Caldwell et. al., 1998) standards have been developed and are being implemented. The achievements of this approach over an 18-month period are extensive.

The first step in standardising the IT infrastructure was the appointment of academic Directors of Information Technology (DoIT) in each of the seven faculties that receive some central funding by the University. The DoITs comprise the major advisory body on IT issues to University management. A Faculty IT Manager (FITM) with a technical background was appointed in each of the faculties with the authority to determine technical issues and responsibility for ensuring compliance with mutually agreed standards. The FITMs developed a network standardisation policy for the entire network, which was adopted by senior management on the recommendation of the DoITs.

All IT staff in the University were offered industry accredited training (Microsoft, Oracle, Novell) as part of a Graduate Certificate in IT—more than 60 staff have enrolled in these courses, which are fully funded by the University.

The NDS tree was rationalised and containers standardised so that all enrolled students could be automatically centrally registered from the student records database. All NDS replicants are required to be maintained on corporate standard servers to maximise availability. There are at least three replicants of each partition and students are allocated to a partition based on the faculty

in which they are enrolled. One replicant is held on a central server while the other two are located near the areas most frequently used by the students in the faculty.

All Novell servers on the network are required to be upgraded to run Novell Netware 5 and deadlines have been set, after which any non-complying server will be disconnected from the network. During the fourth quarter of 2000 the NDS will be upgraded to version 5.1, then the Novell Catalog Service and Single Sign-on will be implemented.

Control of local switching has been transferred from faculties and departments to ITS and data reticulation will be managed on a 'whole of building' basis so that departments can install their servers in a common machine room in each building and be assured of sufficient switching capacity to connect as many end-user devices as there is floor space to accommodate.

The logical topology of the network is also being standardised to eliminate slow proxy bottlenecks.

By the beginning of 2001 the operation of the DLS can be evaluated without the confusion of infrastructure instabilities.

Outcome

The development of the RMIT Distributed Learning System has taken the University from a cottage industry model to a fully fledged enterprise system for flexible online learning, integrated with our legacy student administration system and capable of integration with the PeopleSoft student system when it goes live.

The decision to rapid prototype the development over four release phases has paid dividends. Particularly by developing a widespread understanding, among academic staff, of the opportunities for learning management systems to add significant value to teaching and learning.

The University has established that it is possible to have a central system for flexible learning which is future proofed, by use of the IMS standards, and capable of delivering reliable and secure service to students with a minimum, and reducing, level of access complexity.

RMIT is now in a position to develop a central rapid prototyping courseware production facility which enables maximum engagement of academic staff who do not have the specialised technical skills to produce a useful outcome. The use of meta-content and meta-data catalogued courseware components will greatly assist this.

Rapid protyping of this type of system with short lead times to 'go live' is living life in the fast lane, particularly if the IT infrastructure is being rationalised on a just in time basis. Were we to repeat the process, we might do it differently. The success of the project is due to two major factors: the vision, ingenuity and persistence of the system architects and implementers; and serious executive sponsorship. It would be foolhardy to commit to this type of project without these two prerequisites.

Appendix

Table 1: Phase Overview

Phase	Servers	Courses	Students	Staff	Time in person years	Development Duration	Availability	Hits
1	1	45	720	40	1 year	4 months	90%	-
2	2	225	8342 (5500 active)	165	1 year 2 months	4 months	91.4%	40,000
3	6	797	21,407 (7,415 active)	530	1 year 3 months	4 months	99.3%	280,000
4 (start of semester)	6	933 (404 active)	N/a	N/a	7.5 months	2.5 months	To be assessed	N/a

Example 1: The DLS Learning Hub Interface

The example below shows the DLS interface that academics see after logging in. The student interface is very similar.

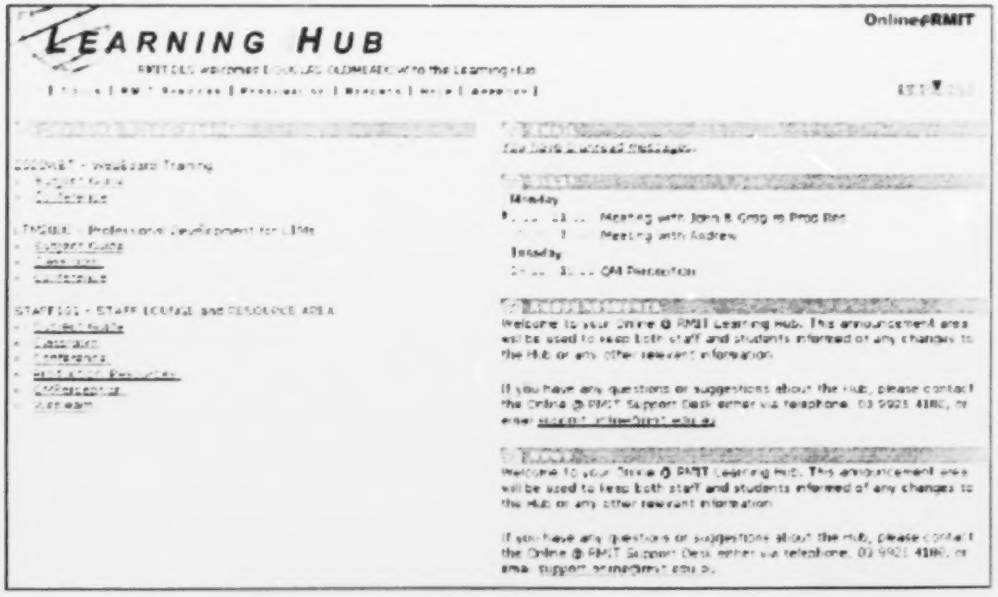

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Diagram 1: DLS Hardware diagram

Note: each server is identified by a different name. It does not reflect the hardware make or model.

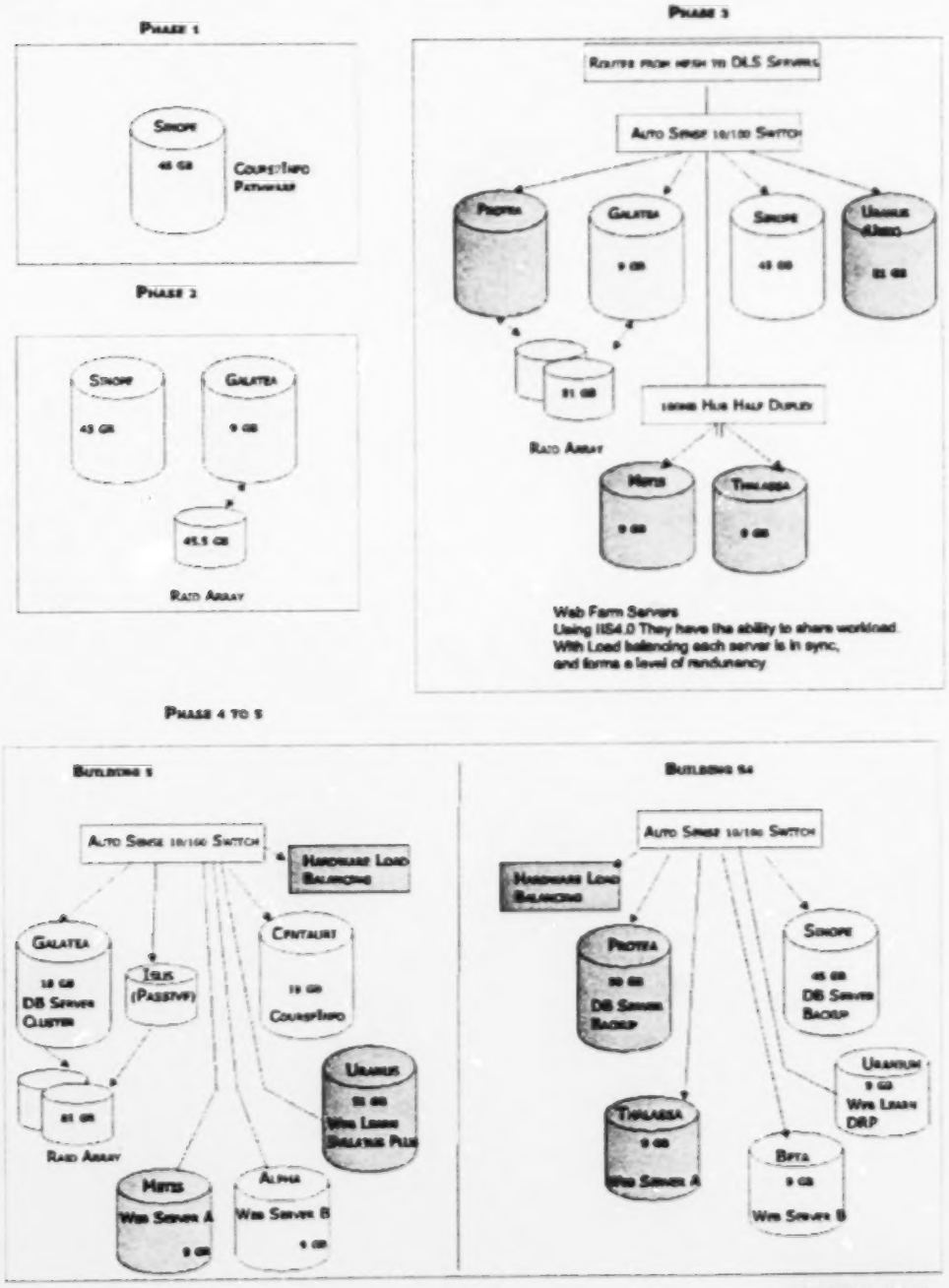

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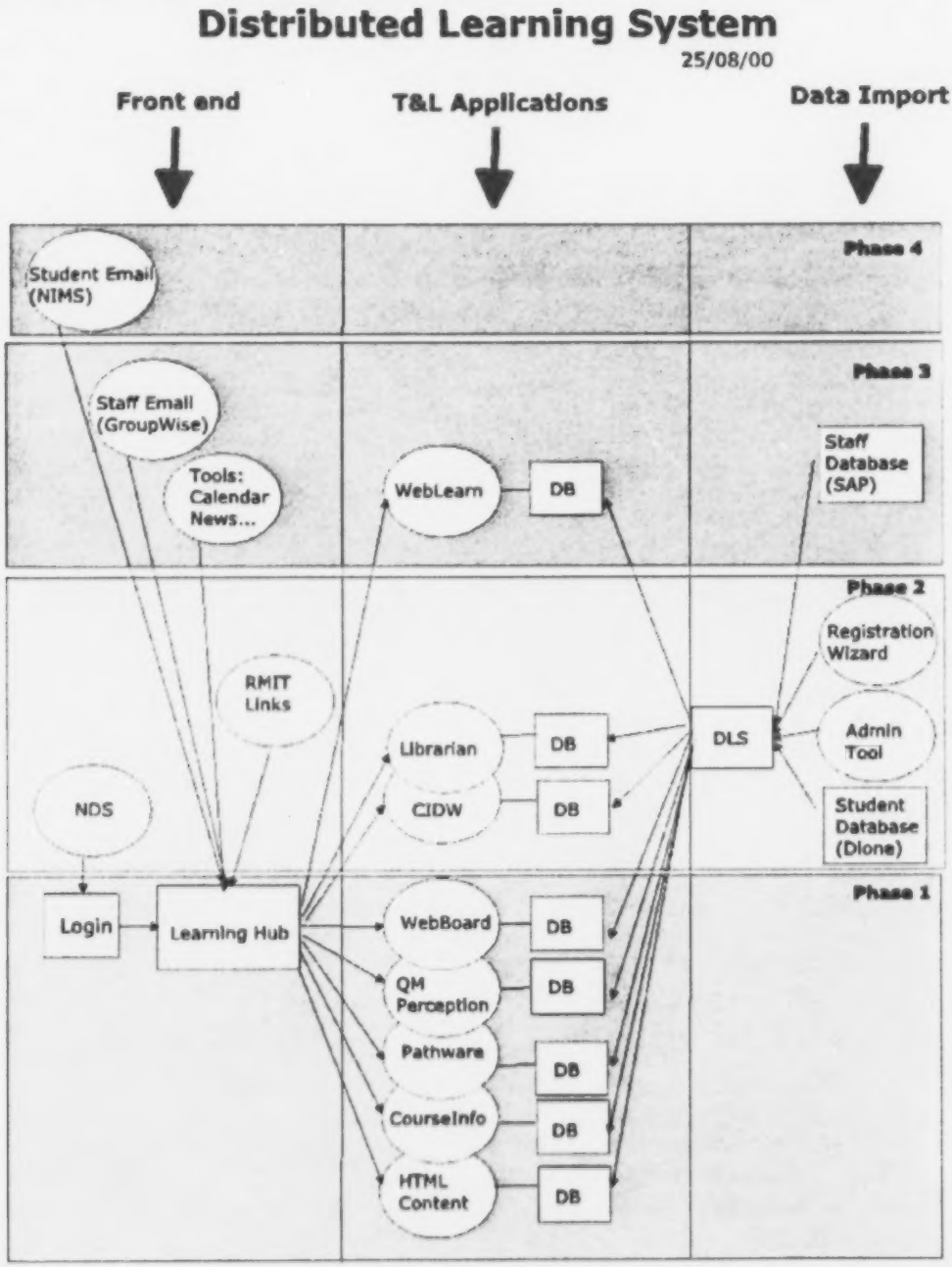
Diagram 2: DLS Software diagram



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Macromedia	Pathware
NDS	Novell
NIMS	Novell
Perception	Question Mark Computing Ltd.
WebBoard	O'Reilly & Associates
WebLearn	RMIT University

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